Global Positioning System Standard Operating Procedures

Introduction

Purpose of Document and Intended Audience

This guidance document will provide a user with an understanding of EPA-Region 2 requirements for collecting locational data with Global Positioning System (GPS) technology. This document will also provide guidance for processing GPS data and bringing it into our Region2 Geographic Information System (GIS). The intended audience of this document includes EPA Region 2 staff, contractors and grantees who are involved in the following activities:

- Planning and oversight of a GPS data collection project
- Conducting GPS data collection in the field
- Maintaining and loaning GPS equipment
- Responsible for post processing GPS data from the field and it's conversion to Geographic Information's System (GIS) data layers and other data formats.

The Region 2 GPS Guidance Document has the following main topics:

1. Planning a GPS Project
2. Field procedures
3. GPS Data Post Processing
4. GPS Data Management In Arcview GIS

GPS can consistently provide accurate locational data coordinates that meet the requirements of EPA's Locational Data Policy (LDP), as well as Regional 5 meter accuracy goals. This is possible when the project is conceived with proper planning, the equipment is used by trained individuals, and the data is postprocessed correctly. If the project is not planned properly the data will be incompatible with both EPA Program and GIS databases. If GPS data collection is poorly performed, or the data is not differentially corrected, GPS coordinates may only be within 100 meters of the actual location. Human error can add kilometers to this outcome.

Region 2 needs to insure that GPS data is collected with proper consideration of the Region's GIS as well as EPA national system (Program) databases. GPS data will need to be accessed through these databases. The Region also must satisfy agency LDP which applies to all EPA data collections that are locationally based. This policy requirement for collecting and documenting lat/long, as well as Method, Accuracy, and Description (MAD) information, applies to all existing as well as new locational data.

For GPS locational data, the Region's compliance with the LDP is supported in part, by the

GPS Field procedures, use of GPS data dictionaries, and the GPS post processing procedures established in these SOPs. Changes in these procedures will be driven by improvements in GPS technology and software.

Each Region 2 GPS data collection effort, must start with approved GPS data dictionaries, developed with the guidance of this document and the Information Systems Branch (212-637-3335 & 3595). These GPS data dictionaries can guide and organize the GPS data collection in the field so that the data will be useful for both scientific, and information management purposes.

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1. Planing a GPS Project

To insure that the GPS survey is successful, appropriate planning activities must be undertaken before the survey is performed. Planning should include the following:

- The objective(s) of the project should be established.
- Database considerations and GPS data dictionaries design.
- Data management responsibilities delegated and File Naming convention understood.
- GPS Field Survey requirements (Technical training, Field training & site knowledge.)

These four (4) planning steps are crucial to get accurate locational data that is compatible with EPA programs and GIS databases. Poor project planing can result in inaccurate or incomplete data.

Establishing the objective(s) of the Project

The objectives of the project should be clearly understood. Write down the purpose of the data collection and the type of data that is to be collected. Are you collecting new data, or improving your existing locational data? Is it possible for you to collect data for more than one program? Determine which program(s) might be included in the GPS data collection effort. From the selected program(s), which features (locations) are going to be acquired with GPS (e.g., front door, main gate, discharge and/or monitoring locations, treatment unit...)?

At this time it should be understood that your locational data collection effort should meet Region 2 requirements. This means that the accuracy *goal* for collected data should be +/- 5 meters, that whenever unique ID's exist in Program and GIS databases they should be used, and that every GPS'd feature has Method Accuracy & Description attributes.

Database considerations and GPS data dictionaries design.

GPS Locational data must be relateable to existing EPA Program and GIS databases. The primary consideration after identifying the database related to your GPS data collection is to identify the unique ID or "key" used for the features you will locate. The unique identification of an EPA regulated point or area in a Program database will often require a Facility level as well as sub facility level ID and possibly more. The next step in the planing process is designing good data dictionaries with these identifying keys. Data dictionaries are created with the Trimble's PathFinder Office Software and loaded into the Datalogger. In the field, a data dictionary prompts the GPS field operator to enter the database key(s) and and other attribute information to identify the point or area being collected. This information will be automatically tagged or attached to the locational data (latitude and longitude). A well thought out data dictionary(s) should be designed and field tested prior to actual data collection.

To create a good data dictionary, the elements of each database involved in the project should be "mapped" or scrutinized in order to understand what are the key identification fields. In this way you can correctly choose the database fields that will uniquely identify the features for which you want to acquire GPS locations.

- *Example*: If you are interested in obtaining locational data for PCS (Permit Compliance System) monitoring points, you would need to enter the facility level ID (NPDES ID), the discharge pipe id (DSCH ID) and the monitoring point ID (DRID) in order to uniquely identify a PCS monitoring point.

All Region 2 data dictionaries must also contain the field "MAD_DESCRP". This field should provide a physical description of the feature whose location is being GPS'd. "MAD_DESCRP" is one of the Method Accuracy & Description (MAD) metadata attributes required by Agency LDP. All other required MAD fields will be automatically generated by the "Region 2 GPS Data Mgmt. Tool-Trimble" (See section 4."GPS Data Management in ArcView GIS").

A GPS data dictionary will have it's own file for the day. A dictionary file can receive many points or areas. For each day of GPS data collection, 1 file for each data dictionary used that day, should be created in the GPS data collector. A single data dictionary is usually all that is required for most Region 2 GPS data collection efforts.

Data dictionaries can contain different types of point and area features. A particular point or area feature type, can be selected from a list in the data dictionary by the crew member operating the unit. Each feature will appear to the user as a separate data input screen. For example:

> Permit Compliance System (PCS) GPS data projects, might use a data dictionary with three separate features: an *end of pipe discharge point* feature ("pcs_d_pt"), a *pipe monitoring point* feature ("pcs_m_pt") and a *discharge area* feature ("pcs_d_area"). They are each data dictionary *features* in the PCS data dictionary. Many features of these three types can be captured in the PCS data dictionary file, for that day.

File Naming Convention

The Region 2 file naming convention should be understood at the planing stage and should be followed at all times. Our file name convention provides for consistency among file names as well a way to locate the source data for quality control purposes.

The maximum number of daily GPS files created from one GPS crew, should be one file for each data dictionary used that day. Each file should be named using the Trimble default fill name with a small modification. The default file name has eight (8) alpha-numeric characters and should start with a default letter for the data collector used. This letter will have been set by the Region 2 GPS Program Coordinator and will be unique for each Region 2 Trimble Data Collector. This letter must not be changed. Following the first letter will be the month, day and military hour as 6 numbers. The 8th and last character is a letter. The user should backspace from the 8th through the 6th space (military style hour) in the default file name and modify these three characters to be a 3 character abbreviation for the data dictionary being used. These 3 characters will provide crew members with the ability to discriminate between the data dictionary file names on the data logger, if more than one data dictionary was used in a day..

For example, in the case of the PCS data dictionary, the Trimble default file name of

- **E061117A** should be modified to: **E0611PCS**

Remember, every data dictionary used for Region 2 GPS data collection efforts must be approved by the Information Systems Branch. Upon approval a 3 letter acronym for the data dictionary will be assigned.

GPS Equipment and Training

The purchase and or use of GPS equipment by EPA Region 2 Programs, Grantees, or contractors must be approved by the Regional GPS coordinator (Michael Glogower). This is necessary to make sure that the equipment used for a regional project meet regional and agency requirements such as:

- Attribute entry (facility/site identification) capability
- EPA Locational Data Policy (LDP) Metadata creation
- Accuracy capability

Trimble Pro XR and XL GPS packages meet these requirements and can be loaned from the Region 2 GPS Coordinator. Personnel must be trained in the use of the GPS equipment and the Standard Operating Procedures before any data collection takes place . To arrange a training session with Region 2 Trimble equipment, contact the Regional GPS coordinator (Michael Glogower). .

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2. Field Procedures (GPS 001 - Revisions 03)

These field procedures were developed by the regional GPS coordinator Michael Glogower (Surveillance and Monitoring Branch) and approved by Randy Braun (Surveillance and Monitoring Branch) & Robert Runyon (Chief).

Introduction

These GPS field procedures provides guidance for the use of EPA's Code-Based Global Positioning System (GPS) equipment. It gives guidelines for users of TRIMBLE Navigation's Pathfinder PRO XL and PRO XR GPS receivers with Trimble models (TDC1 & TSC1) hand held Datalogger as well as the older Corvallis Microtechnology (CMT) MC-V model Datalogger. These procedures will address topics that are necessary so that the reader has a basic understanding of what is involved in collecting locational data. This section will address a locational data project from start to finish, and will include; GPS project planning, recommendations for GPS survey planning, GPS equipment setup (Critical Parameters),GPS use and field notes.

GPS can consistently provide accurate locational data coordinates that meet the requirements of EPA's Locational Data Policy, but only when the GPS equipment is used by trained individuals, is coordinated with proper planning, and the data is postprocessed.

Planning a GPS Field Survey

To insure that the GPS survey is successful, appropriate planning activities must be undertaken before the survey is performed. These planning activities should include:

Facility/Site knowledge preparation.

Review of data dictionaries and file naming convention.

Factors that might limit the use of the GPS equipment should be assessed.

If a GPS survey is properly performed, and the data is differentially corrected (or postprocessed), users can expect to obtain accurate locational data that always meets the

Regional GPS Policy goal of ± 5 meters. If the survey is not properly planned, is poorly performed, or the data is not differentially corrected, users can expect the results to be within 100 meters (95 percent of the time)of the actual location. GPS operates best when the receiver has a clear view of the sky. Problems can be experienced when working under very heavy tree cover, or in urban areas with large buildings.

The first step in the planning process should be to determine what sites, and which site characteristics, are going to be located. A plan should be formulated to collect the desired locational data in a logical manner, which makes the best use of the time available. Personnel should become familiar with the site(s) before data collection begins, and an effort should be made to determine exactly where the locational data will be collected (i.e. at the front door, main gate, at the treatment unit, centroid of the site, etc.), this is called "feature mapping". Maps and directions to the site(s) should be obtained, and site maps are very useful to have in the field. For large or complicated Facilities a pre-survey meeting with the Facility Environmental Coordinator should be scheduled to 'feature map' desired points and areas.

If the field crew is going to be collecting information about the location ("attribute data") using the older Corvallis Microtechnology (CMT) MC-V model data logger, or more recent Trimble models (TDC1 & TSC1) data loggers, then a well thought out data dictionary should be designed and field tested prior to actual data collection. A data dictionary is used to provide data about the locational data collected, and although a data dictionary is not necessary to capture GPS positions, it makes sense to record relevant attribute information to the positional data collected. The information that the data dictionary can collect is attached to the location data, and it can be either site or program specific. A data dictionary is created on a PC using the PathFinder Office (Ver 2.11) software, and must be transferred from the PC to the data logger before it can be used.

The collection of locational data will be scheduled to coincide with proper satellite availability, and favorable satellite geometry, in order to optimize the accuracy of the locational data collected. GPS positions must not be collected unless at least four satellites are observed by the GPS receiver. In addition, satellite geometry must be favorable, and a Positional Dilution of Precision (PDOP) of six or less is available. Locational data should not be collected during periods when there are less than four satellites visible to the receiver and/or if the PDOP is greater than six.

In order to obtain GPS positions that meet the Regional LDP (i.e. ±5 meters), the remotely collected data must be differentially corrected against a Base Station that is collecting data simultaneously, and which is within 200 miles (320 kilometers) of the Base Station. EPA's Base Station in Edison, New Jersey operates seven days a week from 7:00 am to 7:00 p.m. Several distances measurements from the Edison Base Station are shown in Table 1 attached.

The NJDEP in Trenton, New Jersey also operates a Base Station, however it operates only on weekdays from 7:00 am to 7:00 PM. Additional hours can be provided , if necessary by contacting the respective GPS Coordinator. Arrangements have been made with other Base Station operators so that complete coverage of the Region is provided. For northern New York State we may access the Vermont Agency of Transportation in Montpelier, VT, in western New York State we can access the Allegheny National Forests' Base Station, and in Puerto Rico we can access either Marel Bayamon, Inc., or (by March 1996) the US Forest Services Base Station in the El Yunque Rain Forest.

Table 1

Places & Their Distance from Edison, New Jersey

Place Name	Miles	Kilometers
Albany, New York	150	241.35
Binghamton, New York	135	217.22
Boston, Massachusetts	210	337.89
Buffalo, New York	300	482.70
Cape May, New Jersey	117	188.25
Corning, New York	182	292.84
Dunkirk, New York	290	466.61
Elmira, New York	167	268.70
Lake Placid, New York	260	418.34
Long Island, NY (eastern end)	135	217.22
Massena, New York	305	490.75
Montpelier, Vermont	274	440.87
Niagara Falls, New York	300	482.70
Old Forge, New York	223	358.81
Philadelphia, Pennsylvania	60	96.54
Pittsburgh, Pennsylvania	300	482.70
Plattsburgh, New York	292	469.83
Portland, Maine	300	482.70
Rochester New York	247	397.42
Syracuse, New York	200	321.80
Washington, D.C.	183	294.45
Watertown, New York	252	405.47

*Source: From AUTOMAP

Mission Planning Software

The QUICK PLAN for Windows program can be used to provide projections of satellite visibility. The most important information provided by this software package is the number of visible satellites, the PDOP (how good the satellite geometry is), and the specific satellites that will be in view. These data are presented in a graphical manner for ease of use. Also useful, if

you are having trouble receiving satellite signals, is a table that shows the azimuth and elevation of each satellite. In order to accurately make correct forecasts of satellite availability, the program requires a recent ALMANAC.

Although an ALMANAC can conceivably be valid for up to three months, it is best to use the most recent one available, because older ALMANACS can provide erroneous information. An ALMANAC can be transferred from a remote receiver that was used in the field for over 15 minutes, or it can found in any Base Station file. The GPS Coordinator can provide up to date information and advisories to field teams concerning satellite availability and any changes in GPS status.

GPS Equipment Requirements

The planning documents should be reviewed to ensure that GPS data is collected at appropriate times of the day. Plans must be made in advance to obtain and check out GPS equipment before going onto the field. The GPS equipment should be inventoried to ensure that all the parts are there, and batteries should be checked and recharged the day before going in the field.

The Pathfinder PRO XL's and XR's use two external lead acid camcorder batteries as a power source. Although recharging the lead acid batteries normally takes less than two hours, it is recommended that the lead acid batteries can remain on charge when not in use. . The CMT MC-V and Trimble TSC1 Dataloggers' Ni-Cd battery should only be charged when the battery level is 30%, or less. The Ni-Cd batteries must be fully recharged. This requires recharging the MC-V and TSC1 for 15 hours, but it should not be charged more than 16 hours. Overcharging the Ni-Cd batteries in the MC-V can reduce battery life and performance. The internal batteries in the MC-V (five Ni-Cd and one Lithium) are typically replaced every two years by the GPS Coordinator. The Trimble TDC1's are much more susceptible to loosing stored data as there is no internal NI-Cd battery available. Always keep the TDC1 attached to an external power source whether in the field or not.

A checklist of items needed in the field can include; GPS equipment, a range pole, spare camcorder batteries, a backpack, a list of sites to be visited and directions to the sites, maps, QUICK PLAN satellite planning documents, a compass, a tape measure, and a field notebook. The GPS equipment should be tested prior to going in the field in order to ensure that is works properly and that field personnel adequately remember how to properly set up and use the equipment. The procedures specified in the document entitled **" Trimble Asset Surveyor Equipment Requirements"** should be followed to set the critical settings for the GPS equipment, and a sample locational data file should collected.

Obtaining GPS Equipment

If you need to borrow GPS equipment from ESD you should contact the Regional GPS Coordinator (Michael Glogower) to determine if any units are available for loan. If the equipment is available, then a written request should be made to the Surveillance and Monitoring Branch Chief (Roland B. Hemmett), with a copy going to the Regional GPS Coordinator. The request should state why the equipment needed, how many units will be requested, who will be using the equipment, and when it will be returned. In order to borrow ESD's GPS equipment the people that use the equipment should have taken the two day hands on GPS training course.

Performing the GPS Survey

The GPS equipment should be assembled at the site, making sure that the two external lead acid batteries are connected to the GPS receiver, the compact dome antenna is connected to the receiver , and that the MC-V Datalogger is connected to the receiver. The receiver should be turned on before use, since it takes a few minutes for the receiver to begin tracking the GPS satellites.

Critical Settings for Data Collection

Before the GPS unit is used to collect locational data there are several critical settings that must be checked (or set) at least once a day. Critical settings actually affect the quality and usability of the GPS positions collected in the field. The procedures for assigning the proper critical settings are specified on page one of the document entitled **" Trimble Asset Surveyor Equipment Requirements"** (attached). Normally these setting remain in memory when the receiver and Datalogger are turned off, however, it is good practice to verify the critical settings once at the beginning of each day.

In addition to the critical settings, there are several non-critical settings, which affect the behavior of the software on the Datalogger (Asset Surveyor software), and display settings that affect how and in what format the information is displayed to the user, which should be checked or set. Instructions for selecting the non-critical settings are found on pages one and three of the **" Trimble Asset Surveyor Equipment Requirements"**, while the display settings are found on page two.

GPS Status Checks

Before beginning to collect a locational data file you must be certain that the GPS unit is receiving a current position fix. There are several ways to determine this. The fastest and easiest way to do this is to check the *Status Line* at the bottom of the screen on the Datalogger, which indicates the number of satellites being tracked and the PDOP. You need to be tracking at least four satellites (i.e. SV 4/7) to get a good (3-D) position and the PDOP must be below 6. When these conditions are met, then logging GPS data may begin. There may be times when obstructions, such as heavy tree cover, buildings, or topography do not allow the receiver to track four satellites with an acceptable PDOP. If the azimuths and elevations of these obstructions are known in advance this information can be incorporated into the planning software, and the times that GPS will work properly under those conditions can be generated. However, in most cases objects that block the receivers view to the satellites will be unanticipated, and will have to be dealt with in the field. There are several ways to get around this limitation, including;

> The simplest way to handle this problem is to move the antenna slightly, by tilting your body, or move away from the point. However, if you move a significant distance from the point you want to locate you must measure (and record) the distance (in decimal feet or meters) from the point and azimuth (from true north) from the antennas actual location .
>
> Waiting for the satellites to move into better positions. The positions of the satellites can be determined by using the Quick Plan printouts that provide information on where the satellites will be, in conjunction with a compass and a means to determine elevation.
>
> Asset Surveyor comes with a built in offset feature that allows you to record the position of a point without actually being over that point. Offsets which are measured by using a compass and a tape measure, can be entered manually directly into the MC-V at the time of data collection.

Logging GPS Data

Once the Datalogger indicates that at least four satellites are being tracked, and that the PDOP is 6, or less, then the collection of locational data can begin. For a point location a minimum of 120 GPS positions should be logged on the Datalogger. While logging locational data field personnel can be taking pertinent notes and entering the relevant attribute information via the data dictionary in the Datalogger. A typical field data sheet is attached

(Attachment # 2), includes an area to draw a diagram.

* NOTE WHEN USING THE DATALOGGER'S KEYPAD TO ENTER IDENTIFICATION INFORMATION: For those occasions where there is only facility or site level identification available, enter the number zero (0), for required sub-facility level fields if they exist in the data dictionary. When new/other entity level features are found, enter the word *new* in required fields that are of the character type, and *999* in required numeric fields.

Page four of the **" Trimble GPS Asset Surveyor Equipment Requirements"**document gives detailed instructions and step by step procedures to take to collect locational data. There are also instructions for allowable file naming conventions that must be followed. Locational data files should be given names that mean something to the person that the data is being collected for.

After the locational data has been collected and the notes have been completed, the GPS equipment should be packed up. Be sure not to leave any equipment behind.

Upon returning to the office, field personnel shall make copies of the field notes, and give them along with the Datalogger, to the person that will transfer the locational data files into the PathFinder Office software. The two lead acid camcorder batteries that were used should be recharged as soon as possible. They can remain on charge all the time. The GPS data files should be transferred from the Datalogger to a computer as soon as possible, in order to ensure that they are not accidentally lost or deleted.

Procedures are specified for transferring and backing up the files from the hand held data collector (a.k.a. Datalogger)to a computer on page five of the **" Trimble Asset Surveyor Equipment Requirements"** document. The computer must be loaded with the Pathfinder Office Version 2.11 software, which is needed to transfer the files from the hand held data collector to the PC. Procedures are also specified so that the locational data files are backed up to diskette (using the software). Once the files are transferred to the computer and backed up to diskette they should be deleted from the memory of the Datalogger. Files that are deleted from the hand held data collector are not recoverable.

Back at the Office

Remember to recharge two lead acid camcorder batteries, which can remain on charge all the time. Next, transfer the remotely collected locational data files from the MC-V to the PC. Step by step instructions are found on page five of the **" Trimble Asset Surveyor Equipment Requirements"**.document.

Postprocessing the GPS locational data files requires that appropriate Base Station files are obtained from a Community Base station, or from a second receiver (collecting in BASE mode) that is set over a point of known coordinates. Base Station files are collected in hourly file formats. EPA's hourly Base Station files can be obtained via a Bulletin Board Service (BBS) at (908) 321-6663. The hourly Base Station files are self extracting files that are named for the date and time that the data was logged. The format for these files is: E*YMMDDHH*.EXE

where:

E = stands for the EPA (Edison Community Base Station)

Y = stands for the last digit of the year (i.e. 1996, Y= 6)

MM = the month of the year (must use two digits, such as 02 for February)

DD = the day of the month (must use two digits, such as 01 for the first day of the month)

HH = the hour of the day in GPS time (this is equivalent to Greenwich Mean Time)

GPS Greenwich Mean Time Equivalency Table																								
HH	00	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23
EDT	8	9	10	11	MN	1	2	3	4	5	6	7	8	9	10	11	N	1	2	3	4	5	6	7
EST	7	8	9	10	11	MN	1	2	3	4	5	6	7	8	9	10	11	N	1	2	3	4	5	6

HH = the hour of the day in GPS time (this is equivalent to Greenwich Mean Time)

EDT = Eastern Daylight Savings Time (GMT minus 4 hrs = EDT)

EST = Eastern Standard Time (GMT minus 5 hrs = EST)

The Base Station files are collected in TRIMBLE's Standard Storage Format (SSF) and consequently are created with a three letter extension of **.SSF.** At five minutes after the hour the **.SSF** files are compressed and converted into a self-extracting file with a three letter extension of **.EXE.** For example, the hourly Base Station file of E6031519.SSF is collected on March 15, 1996 between two to three pm. At 3:05 pm this file is compressed and converted to a file named E6031519.EXE and is ready for downloading via the BBS. Since the Community Base Station generates a new base file for each hour, base files must be obtained for the period that corresponds to the time when the locational data was collected with the remote receivers. Base Station files from a Community Base Station automatically insert the correct location into the Base file. If another receiver is used as a Base Station then the correct coordinates may have to be entered into these files. This is done in the Pathfinder Office software, in the Reference Position sub-menu of the UTILITIES menu.

In order to differentially correct the locational data, it is normally more efficient to combine the Base Station files for the day into a single file. Before this can be done the Base files must be extracted from their compressed form into files with the **.SSF** extension. To self-extract the file(s) just type in the file name at the DOS prompt while your in the directory that contains the Base Station files. Then, get into the PathFinder Office software and select the appropriate Base Station file from the Combine SSF Files sub-menu of the UTILITIES menu. Make sure that the Sort Chronologically option is selected.

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3. GPS Data Post Processing with Trimble's Pathfinder Office Software

I. Setting up the GPS Project Workspace

Creating a New Project

1. Run Pathfinder Office (PFO). Only once create a "New.." project for your GPS project, using the following steps:

- When the Select Project window first comes up, accept the "Default" project and hit "OK". Then, from the File menu select *Projects*
- In the Select Project window choose "New..". When the Projects Directories window comes up, enter a meaningful project name in the *Project Name* box, but remember, PFO will use the first 8 characters of the project name to create the top level directory for the project directory.

Hit Enter.

- In the Project Directory box, the top-level project directory now has been created under C:\pfdata with the project name. Three subdirectories will automatically be created by Pathfinder Office; "export", "backup" and "base". We will not use these, but instead create a different level of subdirectories ourselves.

2. When you are ready to download GPS data, we will need to add the next level of subdirectories, which will be organized by week. *If your GPS data collection project does not exceed one week then you do not need to add this next level of subdirectories.*

- This can be done when Pathfinder Office is opened buy using either the Modify button in the Select Project window, which is the first window to appear, or by accepting the settings in the Select Project window and using the File menu to select Projects as we did above.
- In either case, use the *Modify* button in the *Select Project* window each time a new weekly subdirectory needs to be created. These weekly subdirectories will be the work place for receiving and differentially correcting the daily GPS files for that week. This is done by simply clicking the Modify button to bring up the Project Directories menu and then clicking in the Project Directory box to change the daily subdirectory name at the end of the project directory path.
- Of the 52 weeks in the year, choose the week number appropriate for this week's data collection. Use the prefix "wk" followed by the week number, then underscore, and the last 2 digits of the year. Your weekly subdirectory might appear as: **wk42_98**
  Hit Return.
- Three (3) subdirectories (*export, backup, and base*), will be created under C:\pfdata\<proj_name>\wk24_98. The "*export*" subdirectory will be used to receive the end results of the post processing which are ArcView (GIS), Shapeless in Geographic Projection and "metadata". These products are the "deliverables" to be given to the Information Systems Branch for inclusion in our GIS database. Metadata is the method accuracy and description (MAD) information describing the GPS data for the week. The "backup" subdirectory can be used to receive a backup of the GPS data downloaded from the data collector unit. More importantly, it can be used at least for the current phase of GPS Data Management SOP's, to receive ArcView Shapeless exported in the projection of our Region 2 GIS Data Library- UTM18-83. In this way the users can view their GPS data immediately in relation to the many GIS Library Information layers available. The "base"subdirectory will receive the daily base station files required to correct the GPS data.
- A project directory path for work downloaded on 10/16/98 should be: C:\pfdata\<proj_name>\wk42_98

3. After altering the weekly subdirectory part of the project directory path hit OK and you will be returned to the Select Project window. It can be seen, that 3 subdirectories under the daily directory were created: Export, Backup, and Base . Hit OK again. Now you can download each day's GPS files directly into the weekly subdirectory. You can then populate the "base", "backup" and "export" subdirectories as described above.

II. Downloading Rover Files

Download and backup on 3.5" disc, of each crew's GPS files (rover files), must be done at the end of every data collection day. When download to the appropriate daily subdirectory in Pathfinder Office and external 3.5" disc, is complete, check to see if the file can be opened in Pathfinder Office. If so, **then** delete the daily rover files on each data collector. This will prevent

the possibility of opening the wrong daily data dictionary file during the next day's data capture.

1. **Download**:
    1. Attach the Rover (GPS Data Logger) cable to the PC.
    2. Turn the Rover ON.
    3. On the Rover:
        1. Press ESC when the it tries to read the number of satellites available.
        2. On the Main Menu select File Transfer
    4. Back on Pathfinder Office:
        1. On the Utilities Menu select Data Transfer. A Data Transfer window will pop up.

            Note: If the connection (to the Rover) fails, check the physical connections (cable) between the Rover and the PC. Check the Port dropdown list box in the upper right hand corner of the DataTransfer window, and choose the correct port.

    5. On the Data Transfer window:
        1. Device: GIS Data logger
        2. Data Type: Data
        3. Direction: Receive
        4. Select the files to be downloaded from the Rover.
        5. Click on Transfer (to actually start the data transfer)
        6. Click on Disconnect to cancel the connection to Rover #1.

        Note: If you disconnect the cable and don't click on Disconnect, PFO will think the first Rover is still connected (even if you connect a second Rover)

    6. To connect a second Rover to the PC and download more data:
        1. Physically disconnect the cable from Rover #1 after clicking on the Disconnect button.
        2. Physically connect the next Rover to the PC.
        3. Click on Connect (to establish communication between the PC and the Rover)

            Note: Repeat the loop as many times as needed to download all the collected data from the Rovers (i.e different crews).

2. **Backup Downloaded Data**
    1. Backup daily data onto labeled floppies (3.5").
    2. Verify that the data (ALL) was actually backed up.

III. Downloading & Uncompressing Base Station Files

1. Download or Copy the base station files for the hours of GPS data collection, by all crews for that day, into the "Base" directory of the corresponding weekly subdirectory.

    For example : C:\pfdata\<proj_name>\wk42_98\base

2. Uncompress base station files (if needed). To uncompress the base files:

    In Windows 3.x:
    1. Program Manager: In the File Menu, select Run.

2. Type in the path and name of the compressed file (name.exe).

   OR

   In the File Manager: Go into the corresponding "Base" directory; double click on the file.

In DOS:

1. Change to the corresponding base directory (cd <DirectoryName>) where the base station file (.exe) is.
2. Type the name of the base station file (FileName.exe) and hit Enter.

In Windows 95/98

1. In the Start Menu, click on Run...
2. Type the path where the base station file is located. *For Example: C:\pfdata\<proj_name>\wk42_98\base\basefile.exe*

   OR

   In Windows Explorer: Go into the corresponding "Base" directory; double click on the file.

IV. Differential Correction

1. Coordinate System & Units Set Up in Pathfinder Office (PFO)

**Note: The settings described in this sub-section (1) need only to be set once.*

*A. Select **Options** from menu bar*

*- Select **Units***

Distance: meters

Area: square kilometers

Velocity: kilometers per hour

*Offset: meters**

**Note: The units for Offset are meters and it applies to the display and reporting of Offset and Standard Deviation data in Pathfinder office. It is important to make sure that the >Offsets= field in the configuration menu for the data logger are set to meters and that GPS crews take offsets in meters.*

Offset Distance format: Slope distance and Inclination

Precision: Meters

Confidence: 95% Precision

North Reference: True

Click Ok to exit Units

*B. Select **Options** from menu bar*

*Select **Coordinate System***

Select by: Coordinate System and Zone

System: Latitude/Longitude

Datum: WGS 1984

Altitude measured from: Height Above Ellipsoid

Altitude units: meters

Click Ok to exit Coordinate System

*C. Select **Utilities** from menu bar*

*Select **Differential Correction***

*Click on **Settings** to configure the Differential Correction*

On the Differential Correction Settings window:

*Select the **Output Tab***

- Output Positions: Corrected only

- Audit File Contents: Standard

*Select the **Base Options Tab***

- Reference Confirmation: Always required

- Filter minimums: Elevation: 0 & SNR: 0

*Select the **Code Processing Tab***

- Rover Processing Technique: Standard

- Correct Velocity Records: Keep it UNCHECKED

- Correct Realtime DGPS Positions: Keep it CHECKED

- Base Processing Technique: Standard

*Select the **Zipped Files Tab***

- Keep all boxes UNCHECKED

Click Ok to exit Settings to return to the Differential Correction window

2. To Differentially Correct your Rover (field collected) files

*A. Select **Utilities** from the menu bar*

*- Select **Differential Correction***

Rover Files: Select these files (.ssf) by clicking on the Browse button.*

Base Files: Select these files by clicking on either :

- Local Search (this searches your default Base folder)

- Internet Search (searches from a list of Base Stations)

- Browse (this searches your default Base folder)

Note: Verify that the Base File coverage is FULL.

Corrected Files: These files will automatically go into the default output folder for the Project.

*File Extension: *.cor*

Processing: Select Code Processing Only

Click OK to exit the Differential Correction window

You should get a message saying: "100% of the selected positions were corrected". If this is not the case click on More Details to check which files had problems.

1. **Quality Control (QC) Editing**

After the **.ssf* files have been differentially corrected you should open each file and edit it in order to maintain quality control over the collected data. Editing can improve the accuracy of point features by eliminating outlying positions from the averaged point coordinates. Editing should be done according to accuracy requirements of the project. The reduction in the spread of points is one of seven GPS parameters used in the Region 2 GPS accuracy estimation. All Region 2 GPS data collections should strive for 5 meter accuracy. 120 pre-edited positions should be collected for point features with an accuracy requirement of 5 meters or better. Two (2) important things should be kept in mind when doing the QC editing, the standard deviation and the number of positions per point feature.

1. In order to support 2 meter accuracy, a point feature must be edited when the Standard Deviation (SD) is greater than (>) 1.0 meters . Standard Deviation (or spread of contributing positions) is one of seven (7) GPS parameters sampled by Region 2's ArcView GPS Data Management Tool when estimating GPS point accuracy. Please see Section VI "GPS Data Management In ArcView" for an explanation of this tool.
2. A minimum of 90 positions per point feature (after making any editing) are required in order to satisfy the position count requirement for both 1 and 2 meter accuracy. Less than 30 net positions will result in a "redo" accuracy assignment.

Quality Control Editing steps for points requiring better than 5 meter accuracy:

Under the "View" menu first choose *Map,* then *Time Line*. Arrange the windows. In the "File" menu select Open; (Select a corrected file by typing "*.cor" in the "Open Data Files" window and choosing one from the current weekly workspace).

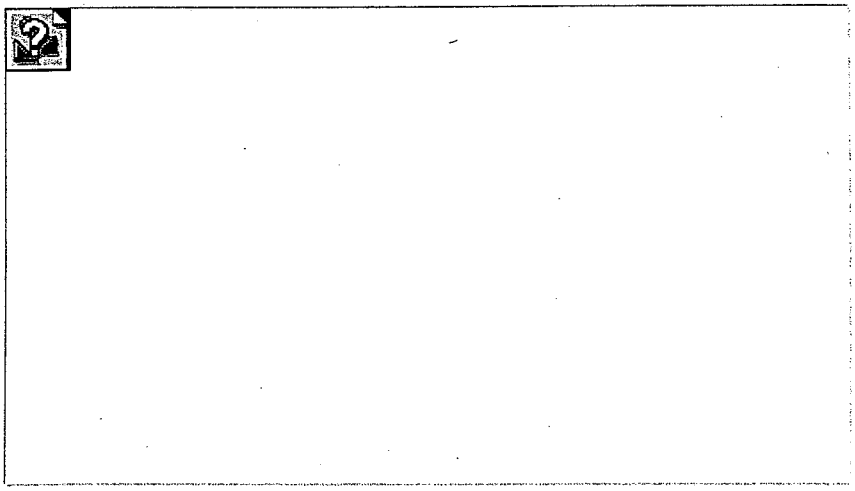
1. <u>POINT Data :</u>

1. Double click on the first point in the time line. The Feature Properties window will pop up. Click through the points using the > button on the Query Feature Window. Observe the Standard Deviation value of each point.
2. Verify that the standard deviation (SD) is less than or equal to 1.0 meters. Edit the point if the SD is > 1.0 meter.

To edit the point:

1. Zoom in on the point to about a 10 meter map extent (as read across the top of the map window), by choosing View - *Scale -Map* and enter 1:10 in the dialog window.
2. Click on Delete on the Query Feature window
3. A message saying : "Do you want to delete the current feature ?" will pop up. Click on Yes.
4. In the Map window, you may have to zoom a little further into or out of the desired area. The bold point will have been replaced by many smaller points, that are the contributing positions. These were acquired at a rate of 1 per second during data collection and averaged to calculate the coordinates of the point feature.
5. Open the Query Position window if it's not opened yet.

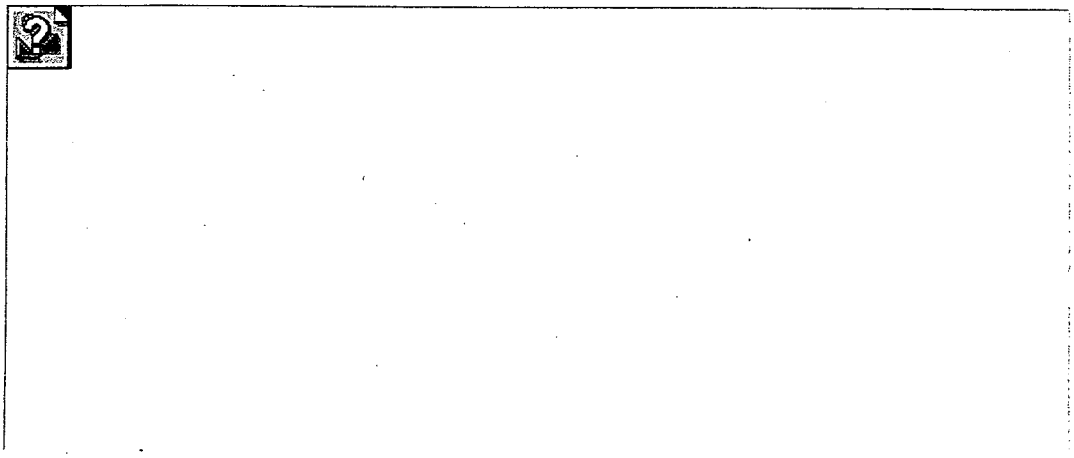
   In the Data menu select *Query Position*
   1. Delete positions in the Query Position window that are outliers. Try to recall from notes, what had occurred during data capture for that point, so that you can determine which positions need to be removed. If this is not available, delete positions from both sides of their spread by clicking through them with the $ button. Keep in mind that a minimum of 90 positions per point feature are needed for 1 meter accuracy.
   2. Close the Query Position window.
6. After editing, click on *Undelete* on the Query Feature window to bring back the point feature you have edited. Often, the *Undelete* button in the Query Feature window will appear to have changed to *Delete*. This is because the focus for that window has accidentally changed to another point feature. Simply click through the points in the Query Feature window until you find a point that has *Undelete* instead of delete as an option. You can then also choose View 6*Auto Pan to Selection* to return to the undelete point in the map extent. Undelete the point.
7. Check the Standard Deviation (SD) again to see if it is now acceptable.
8. Save the file and close it.
   1. In the File Menu select Save.
   2. In the File Menu select Close.



2. POLYGON or AREA Data

GPS Areas should be acquired by taking 5 instantaneous positions at each vertices of the area perimeter. Each vertices must be captured in a regular sequence (clockwise or counter clockwise) along the perimeter. The last vertices taken can **not** also be the first. Area accuracy estimation (especially for small polygons) is much less reliable then point accuracy, and does not involve Standard Deviation.

1. Open the corrected data dictionary file as described above
2. Double click on the desired polygon (area) to be edited. The Query Feature window will pop up - Do not delete the polygon feature.
3. Open the Query Position Window
4. On the Map window, zoom into each of the vertices and using the *delete* option in the Query Position Window, delete those corner points that distort the shape of the polygon from how it appears in the field sketch. Leave 1 (one), point for that corner that provides the truest shape to the polygon.
5. Save and close the file as described above.



V. Loading the .cor Files for Export in Pathfinder Office

The *.cor* (differentially corrected) files also need to be loaded into the Export Utility of Pathfinder Office. We want to Export ArcView ShapeFiles in the Geographic -WGS84 (NAD '83) projection. To do this we only want to load *.cor* files that were produced from the same data dictionary. We do not want to load *.cor* files from different data dictionaries at the same time for Export. We need to run Export with the AEPA Region 2 ArcView Shapefile Geog-WGS84@ format (see Appendix 1 **Pathfinder Office EXPORT SETUP for Arcview ShapeFiles** at end of document). This run will produce Arcview ShapeFiles for our GIS. Pathfinder Office will send all exported data to the export subdirectory of the weekly directory.

From the Utilities menu select Export. (An Export window will pop up.)

In the Export window: Click on the Browse button. In the filename box of the Select Data File window type *.cor. Choose **all** of the cor. file(s). that share the same data dictionary suffix. **Files made with different data dictionaries can not be exported together**.

Verify that the output directory is set up to the corresponding daily export sub directory

In the Choose An Export Setup area choose AEPA Region 2 ArcView Shapefile Geog-WGS84@.

Hit OK

4.GPS Data Management in ArcView GIS

EPA Region 2 staff, contractors and grantees, who are involved in GPS data collection efforts, can access an ArcView tool for GPS Data Management.The tool was designed to easily guide GPS Shapefile data through a sequence of processing steps to create Locational Data Compliant GIS data layers.

The Region 2 GPS Data Management Tool is an ArcView Extension that the user can load in ArcView by simply choosing the "Extensions" choice from the "File" drop-down menu in the ArcView Project Window.

Look for "Region 2 GPS Data Management Tool-Trimble". It is a good practice to load the extension right after you have chosen to open a a new project in ArcView.

The GPS Data Management Tool has the following capability:

1. Merges ArcView Shapefiles while preserving all attribute fields in output. Source Shapefiles are not changed. Single Shapefiles will be reproduced in the same way but without merging.

2. Adds signed Latitude and Longitude attributes, (decimal degrees with 6 decimal digits), to Shapefiles having Geographic Coordinates. Also checks for existing GPS related fields, and then adds additional, GPS metadata fields.

3. Estimates GPS accuracy.

4. Exports and Merges GPS metadata. When a user cycles through all 5 options under the "Make GPS Metadata" menu, the R2 GPS Data Management Tool

insures that the ArcView Shapefile output is a Locational Data Policy compliant GIS information layer. Each merged Shapefile has an associated GPS metadata file created. These metadata files should be merged together as the last step. The user can then decide to use the tool's third menu "Project GPS" to create a copy of the output in the same projection as our Region 2 GIS Spatial Database.

5. Projects the output Shapefile (which is in the Geographic coordinate system) into the user's choice of Puerto Rico State Plane or UTM Zone 18. There is no datum conversion capability. The datum is not changed from WGS84 and conforms to other GIS layers in NAD83. There is a third 'Project GPS' choice for user defined input projections, (same datum), but since all GPS data will be exported only as Geographic WGS84 this choice won't be used for GPS data.

At the present time, in order to cycle through all 5 items under the "Make GPS Metadata" menu, your ArcView Shapefiles must be created using Trimble's Pathfinder Office Ver. 2.11 software. This software is the differential correction software used to post process your Trimble GPS data.

The GPS Data Management tool takes the form of 3 menus in the View Window with drop-down selections (items). The three menus are:

1. "Merge GPS Shapes"

2. "Make GPS Metadata"

3. "Project GPS"

Users need only to step through these menus in sequence to process their GPS Shapefiles (Geographic Coordinate System).

Procedures for Full Processing of GPS ShapeFiles in the Region 2 GPS Data Management Tool - Trimble

It is important to remember that you must first bring all of your GPS Shapefiles into one or more views in a ArcView project where the "Region 2 GPS Data Mgmt Tool-Trimble" extension has been loaded, before using the tool's menus.

- 1. Bring all of your GPS Shapefiles into one or more views in a new ArcView project. In this new project you will have enabled the Region 2 GPS Data Mgmt. Tool-Trimble extension. If the GPS data collection project was more than a short term effort, then the same feature type (i.e. ArcView theme or Shapefile name) was probably exported at different times in the course of GPS data collection and post processing. In this case bring each post processing event's Shapefile(s) into a different view and use the pathname and Shapefile directory as the View name. This can be done by copy & paste when you "Add Theme" in ArcView, and then choose "Properties" under the View menu. Now you can better determine if all of the data you want the tool to process has been brought into the ArcView Project. If you have only one exported Shapefile or set of shape files from the GPS data collection, put this Shapefile(s) into a single View.

- 2. When you have brought all your shape files in the project, open a new View. This will be your Region 2 Data Mgmt Tool workspace. You might want to give this View the name "merge_<date>". Choose the ***'Find Themes to Merge'*** selection from the ***"Merge GPS Shapes"*** menu. Make your choices. If the tool brings back more than one theme into the workspace View, then choose the ***"Merge Themes and Add To View"*** option from the same menu. Repeat these steps until there are no Themes presented to you in the List Message Box that prompts the user to: "Choose a Merge Theme that will be found in each of the Views you have chosen".

- 3. Now, when all shapes have been merged or duplicated in the workspace View, you

can continue with the GPS Metadata processing loop by simply clicking the numbered (1 through 5) selections of the ***"Make GPS Metadata"*** menu. Each selection (1 through 5) of the "Make GPS Metadata" menu, needs only to be run once.

- 4. When finished you should merge the .dbf metadata files created for each of the merged Shapefiles into a single metadata file. To do this use the ***"Merge Metadata dbf's"*** selection from the "Merge GPS Shapes" menu.

You can lastly choose the appropriate projection you would like to put your processed Shapefiles in by using the ***"Project GPS"*** menu. This will allow you to view your GPS Data Layers on top of any Region 2 GIS Library layer in ArcView and use the Region 2 Environmental Cartography Kit to do spatial analysis.

Region 2 GIS spatial data for New York and New Jersey is kept in the UTM - Zone18 projection, NAD83 datum. Puerto Rico spatial data is kept in Puerto Rico State Plane (meters) projection, NAD83 datum. Before you project your merged Shapefiles it would be a good idea to first create a sub-directory in the ArcView project workspace named "UTM" or "PRSP" (for Puerto Rico State Plane). You will need to put your projected Shapefiles into this sub-directory when prompted.

The tool can provide help for other tasks as well. Depending on their needs, users can use some menus items independently without cycling through all of the tool's menus. However, depending on the utility they require, they may have to follow an established sequence of menu choices.

For example a user can merge dBASE (.dbf) files using the "Merge Metadata .dbf's" option under "Merge GPS Shapes" without following any menu sequence. In the same way a user can use any of the projection options under the "Project GPS" menu.

But if users want to merge non GPS Shapefiles, they must start with the first option under "Merge GPS Shapes" which is "Find Themes to Merge".

The GPS deliverables to Region 2 Information Systems Branch (ISB) for all Region 2 GPS data collection projects are the fully processed un-projected (i.e. Geographic Coordinate System) ArcView Shapefiles and merged Metadata file output from the "Region 2 GPS Data Mgmt. Tool -Trimble".

Please Contact Bob Simpson - ISB at 212 637-3335 regarding these deliverables.

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5. Appendices

Appendix 1: Pathfinder Office EXPORT SETUP for Arcview Shapeless (to be done only once)

Setting up the ArcView Shapefile export format

From the Utilities menu select Export. (An Export window will pop up.)

On the Export window:

Click on the Browse button to select the input files to export.

Verify that the output directory is set up to the corresponding export directory.

In the 'Choose and Export Setup' area of the Export Window choose Sample ArcView Shapefile Setup from the ones listed.

Click on New Setup button to create a new Setup of the ArcView Shapefile type selected. (An Export Setup Name window will pop up.

On the Export Setup Name window:

Enter a name for a new export setup. In this case the name is "EPA Region 2 ArcView Shapefile Geog-WGS84". An Export Setup window of the selected type will pop up with 6 tabs (Format, System, Attributes, Units, Coordinate System, and Position Filter) to be set up.

On the Export Setup window:

On the Format tab:

Format: ArcView Shapefile

Type of Data To Export: Feature - Positions and Attributes

On the System tab

System File Format: DOS Files

On the Attributes tab

Select the desired Trimble's Metadata to go into the export files.

1. Export Menu Attributes As: Attribute Value
2. Generated Attributes:

   For All Feature Types:
   1. PDOP
   2. Correction Status
   3. Date Recorded
   4. Time Recorded
   5. Feature Name
   6. Data File Name
   7. Total Positions

   For Points:

   1. Height
   2. Standard Deviation
   3. Horizontal Precision

   For Lines:

   1. Does not matter if no lines are collected.

   For Areas:

   1. Area
   2. Perimeter
   3. Worst Horizontal Precision

On the Units tab

Units

1. Use Export Units
    1. Distance: meters
    2. Area: Square kilometers
    3. Velocity: Kilometers per hour

On the Coordinate System tab

1. Select "Use Export Coordinate System" and Click on the Change button. A Coordinate System window will pop up, set the following values:
    1. Select By: Coordinate System and Zone
    2. System: Lat/Lon
    3. Datum: WGS84
    4. Coordinate Units: (METERS will be grayed out)
    5. Altitude Units: Meters
    6. Altitude Measured From: Height Above Ellipsoid (HAE)
2. Click on the OK button

- On the Position Filter tab
    1. Select the following values:
        1. GPS Position Criteria:
            1. Minimum Satellites: 3D (4 or more SVs)
            2. Maximum PDOP: Any
            3. Include Positions That Are:
                1. Non GPS
                2. P(Y) Code
                3. Differentially Corrected
                4. Realtime Differential
                5. Phase Processed
                6. Survey Grade

Appendix 2: Region 2 GPS Accuracy Estimation

Script uses ratios of horizontal 1dRMS error values to std_dev values. These ratios were estimated from Trimble's "Time Dependence of Averaging" test plots of horizontal Standard Deviation and horizontal RMS error as a function of occupation time (see "Characterizing Accuracy of Trimble Pathfinder Mapping Receivers by Grant Marshall of Trimble Navigation Limited Surveying and Mapping Systems Commercial Systems Group").The ratio values are based on the Y value (cm of error or std_dev) at the intersection of the two curves. This equivalence value (49 cm of 1dRMS error or std_deviation) occurs at approximately 7.14 mins occupation time under optimum conditions and insignificant base2rover distance. Thereafter 1dRMS decreases and std_dev increases.

The Trimble graphs aim to characterize the time and distance dependence of accuracy (RMS error). Five 1dRMS-to-std_dev ratios for five occupation intervals (range is 0.5 mins to > 25 mins) are estimated by rsimpson using Trimble's graphed data for each of four base2rover distance intervals. Three additional equivalence points were also estimated based on 10cm of additional base2rover distance incurred error at 50km, 100km, and 150km base2rover. At 150km base2rover distance (an additional 30 cm of instantaneous RMS error) and 30 minutes occupation time, the curves are essentially asymptotic.

The time dependence effect, as estimated in the ratios, is presented as 5 "if..then" statements nested in 4 distance dependent "if..then" statements in the script. The std_dev value is multiplied by the appropriate ratio to estimate the 1dRMS error (intersection of curves) for that distance and occupation time. The product of "ratio * std_dev" for an occupation time interval at base2rover greater than 150 km is increased by 2ppm (10cm/50km) error [(std_dev * ratio) + ((base2rover -150000) * .000002)]. The recalculated std_dev is added to Trimble's horiz_prec value as an estimate of the 2dRMS error. This value is the estimated accuracy of the point and now should also reflect non zero mean noise, bias and blunders encountered under less than optimum conditions.

It needs to be confirmed that the ratios should work for all Trimble receivers. The assumption is based on the fact that a "horiz_prec" value incorporates the specific 1dRMS error (which appears to be the instantaneous 1dRMS error) computed for each of Trimble's receivers. The behavior and relative values of the std_dev & RMS curves is also presumed to be the same at each model's different instantaneous 1dRMS value.

The 2dRMS estimate is conservative as Trimble's horiz_prec = [(Receiver specific optimum 1dRMS value * average PDOP) + ((receiver specific ppm value (i.e PRO XL's = 1ppm)) * base2rover distance)]. Also, the distance dependence of 1dRMS error is assigned a factor of 2 ppm in the script calculations.

MCORR400 is assumed to be the correction software.

Accuracy Estimation Parameters:

A. Points

theRecalStd_dev Val is based on ratios of horizontal 1dRMS error values to std_dev values. These ratios were estimated from Trimble's Time and Distance dependence of 1d RMS error (accuracy) test plots.

theBaseloggin_factor = ((((theBaselogginVal/5).Sqrt).Sqrt).Sqrt)

Average Horizontal Precision = [(Receiver constant (error built into the receiver)) * (Average PDOP)] + [(base2rover) * ppm(distance factor)]

theMad_accurcVal.= ((theHorz_precVal + theRecalStd_devVal) * (theBaseloggin_factor))

B. Areas

theBaseloggin_factor = ((((theBaselogginVal/5).Sqrt).Sqrt).Sqrt)

Worst Horizontal Precision = [(Receiver constant (error built into the receiver)) * (Worst PDOP)] + [(base2rover) * ppm(distance factor)]

theMad_accurcVal = ((theHorz_precVal * 4) * (theBaseloggin_factor))

For comments or questions about this page contact:

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~~NADA~~ see page 18

NAD 83

shape file

convt. to project the base map.

Speak to Gallo regarding conv.

Bob Simpson
Regional ~~EIB~~ ISB
3335